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DWARF EGGS OF THE DOMESTIC FOWL

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BULLETIN 255.

DWARF EGGS OF THE DOMESTIC FOWL.[1]

By Raymond Pearl and Maynie R. Curtis.

In any breed of domestic fowls there are occasional individuals which produce one or more small eggs which are from one-tenth to one-half the size of normal eggs. Various superstitions have been associated with these small eggs and in many parts of the world the eggs are still called by names derived from the superstitions formerly common to the region. A common superstition which persisted nearly to our own time was that old cocks produced these eggs. Hence they are still often called "cock eggs." At an early period it was believed that if a cock egg was incubated it would hatch into a serpent, the basalisk, whose breath or look was fatal. Other less definite superstitions considered these eggs as good or bad omens. In some places they were used as charms to bring misfortune to one's enemies and were called "witch eggs." In other places they were called "luck eggs" for it was believed that if one was thrown over a building any wish made by the thrower while the egg was in the air was sure to come true. Since no one of these names is generally accepted we have decided to use the modern descriptive term "dwarf eggs."

The dwarf egg is more common than any other type of abnormal egg except the double-yolked egg. It has emerged from the age of superstition with the cause for its production inadequately explained. It is the purpose of the present paper to discuss (1) the different types of dwarf eggs in respect to shape and also in respect to contents; (2) the variability in respect to size and shape; (3) the interrelations of the variations in dimensions, shape and size; (4) the frequency of the occurrence of dwarf eggs compared to normal eggs and of dwarf egg producers compared to birds which do not lay dwarf eggs; (5) the seasonal distribution of dwarf eggs; (6) dwarf egg production by birds with normal and with abnormal oviducts; (7) the relation of dwarf egg production by normal birds to the age of the bird and to the position of the egg in the clutch and litter; (8) physiological conditions which lead to dwarf egg production; (9) the relation of the production of dwarf eggs to other abnormal phenomena of reproduction which either occur in nature or have been experimentally produced; and (10) the contribution which the study of the physiology of dwarf egg production makes to our knowledge of the normal physiology of egg production.

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[1] This bulletin is an abstract of a more detailed paper by the same authors published under the title "Studies on the Physiology of Reproduction in the Domestic Fowl. XV. Dwarf Eggs." Journal of Agricultural Research, Vol. VI, pp. 977-1042, 1916.

In the eight years from February 1, 1908, to February 1, 1916, 298 dwarf eggs are known to have been produced at this plant. The weight of 275 of these was taken and in 261 of these cases the length and breadth was also measured and the length-breadth index calculated. Of the 298 eggs recorded 274 were opened and their contents were examined. Several of the dwarf eggs were floor eggs and a few were laid by birds on which no egg record was kept. In 251 cases, however, the egg record of the bird laying the dwarf egg is available. Further several of these birds were autopsied and the condition of their sex organs observed.

I. DIFFERENT TYPES OF DWARF EGGS CLASSIFIED, FIRST, IN RESPECT TO SHAPE AND, SECOND, IN RESPECT TO PRESENCE OR ABSENCE OF YOLK.

The dwarf eggs of the fowl vary greatly in size and shape. Fig. 51 shows fourteen of these eggs with a normal egg laid

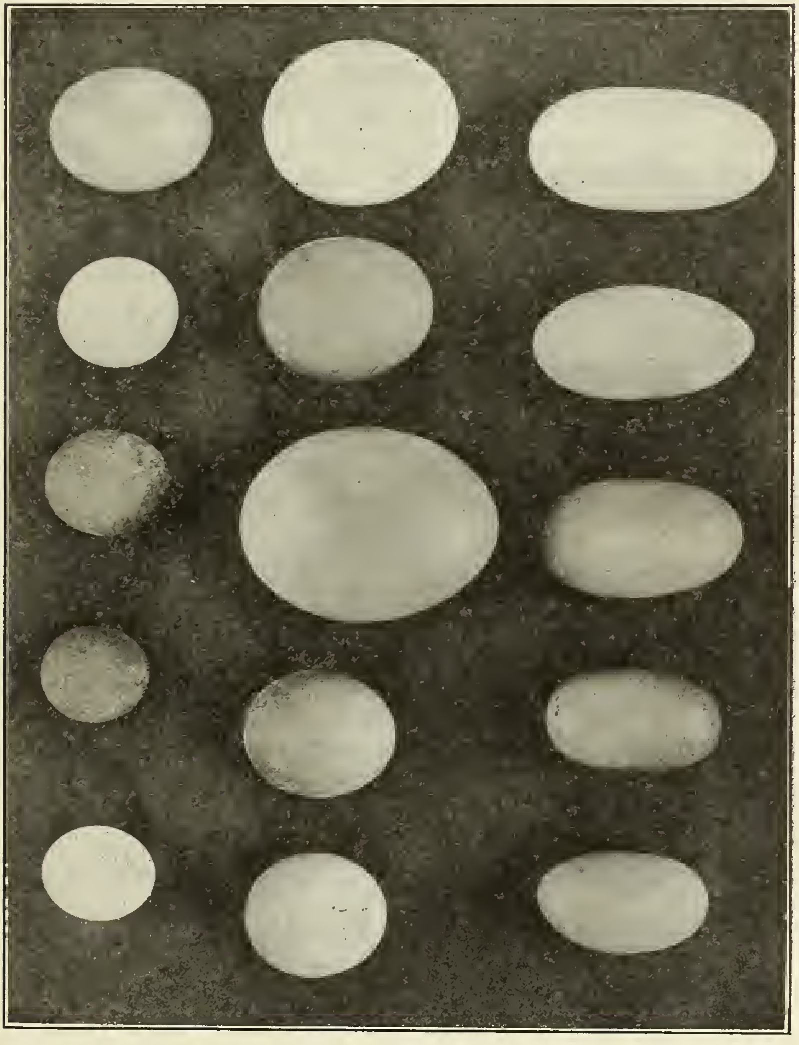

Fig. 51. A collection of dwarf eggs with a normal egg in the center of the group. X 2/3.

by a nine months old pullet for comparison. From this photograph it may be seen that there are two distinct types of dwarf eggs in respect to their shape. The prolate-spheroidal type similar in shape to a normal egg and the cylindrical type which is much longer in proportion to the breadth. The cylindrical eggs are shown in the first column of Fig. 1. These cylindrical eggs occur much less frequently than do the dwarf eggs of the prolate spheroidal type.

Not only do the dwarf eggs differ in respect to size and shape, but there is a difference in internal structure. Some of these eggs contain no yolk but appear to be formed around a nucleus which consists of a few strings of coagulated albumen, apparently untwisted chalazal threads, and there are also sometimes small lumps of hardened albumen or small blood clots associated with these chalazal threads. Some dwarf eggs contain small yolks in yolk membranes. More than half of all the eggs opened, however, contained some yolk which was not enclosed in a yolk membrane. Dwarf eggs may then be classified according to the non-occurrence of yolk and the condition of the yolk when present as, first, yolkless, second, with some yolk not in a membrane and, third with one small yolk. In Table 1 the dwarf eggs are classified both according to form and yolk content.

TABLE 1.

Showing the Classification of Dwarf Eggs both as to Shape and as to Yolk Content.

SHAPE.	Number yolkless.	Per cent. yolkless.	Number with some yolk not in a membrane.	Per cent. with some yolk.	Number with one small yolk.	Per cent. with one small yolk.	Total.
Shape not known[2]	5	38.46	8	61.54	0	0	13
Prolate spheroidal shape	83	33.33	139	55.82	27	10.84	249
Cylindrical shape	8	66.67	4	33.33	0	0	12
Total	96	35.03	151	55.11	27	9.85	274

[2] Dimensions not recorded.

From the last line of Table 1 it is seen that 96, or *35.03* per cent. of the dwarf eggs opened were yolkless. The other

178, or *64.96* per cent. contained yolk. Of these, 151, or *55.11* per cent. of all the dwarf eggs opened contained yolk not enclosed in a yolk membrane. A small yolk was present in 27, or *9.85* per cent. of the dwarf eggs. From these figures it is seen that nearly two-thirds of the dwarf eggs contain yolk.

II. The Albumen and Shell of Dwarf Eggs.

We have seen that dwarf eggs differ in respect to the nucleus around which the albumen is formed. Bonnet[3] states that the nature of the albumen is also generally altered. The dwarf eggs observed differed greatly in respect to the density of the albumen. In many it was very condensed, being a thick clear mass which nearly maintained its shape when removed from the shell and egg membranes. It appeared very much like the albumen in a normal egg while it is in the albumen secreting region, or the isthmus of the oviduct.[4] In many other cases it appeared exactly like the albumen of a normal laid egg, that is, there was a somewhat firm inner mass surrounded by a thin fluid albumen. All gradations between these also occurred. In a very few cases the albumen was more fluid than in the average normal egg. There, however, was an undoubted general tendency for the albumen to be more than normally firm. In connection with another investigation in progress at this laboratory the specific gravity of the albumen of many normal and a few dwarf eggs was determined. The specific gravities of the dwarf eggs ranged widely, with the upper end of the range decidedly above the range for normal eggs. In fact the mean for the dwarf eggs is higher than the maximum for normal eggs, while the minimum for dwarf eggs is only slightly below the mean for normal eggs.

The egg membranes of dwarf eggs so far as superficial appearance indicates are comparable to those of normal eggs. The shell is sometimes entirely or almost entirely absent as in the case of membrane covered or soft shelled eggs which are normal in all other particulars. The thickness of shell varies from very thin to very thick as in normal eggs.

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[3] Bonnet. 1883. Das Vogelei. Deutsche Zeitschrift für Thiermedicin. Vol. 9, pp. 239-252.

[4] Pearl, R. and Curtis, M. R. 1912. Studies on the Physiology of Reproduction in the Domestic Fowl. V. Data Regarding the Physiology of the Oviduct. Jour. Expt. Zool., Vol. 12, pp. 99-132.

III. THE SIZE AND SHAPE RELATIONS OF THE SEVERAL CLASSES OF DWARF EGGS COMPARED TO EACH OTHER AND TO NORMAL EGGS AND THE RELATIVE VARIABILITY OF NORMAL AND OF THE DIFFERENT CLASSES OF DWARF EGGS.

There is a considerable amount of variation within each class of dwarf eggs in respect to every measurable character. For each class of prolate spheroidal dwarf eggs the mean, standard deviation and coefficient of variation for each dimension and for weight was determined by the use of frequency distributions. In the same way the means and standard deviations were determined for shape index. Since this is a percentage character the coefficient of variation has no physical significance. However, the relative variation of the shape in the several groups may be roughly estimated by comparing directly the standard deviations. The number of cylindrical eggs was so small that the variation constants were not determined. The arithmetic means, however, were determined directly from the data. The size and variation of the different egg parts in dwarf eggs is an interesting but difficult question. It was found possible to separate accurately the parts in a dwarf egg with a small yolk enclosed in a yolk membrane. The weights of the parts were determined for sixteen small yolked dwarf eggs. The number is so small that the means, standard deviations and coefficients of variation were determined directly from the data.

The means, standard deviations and coefficients of variation for each character in each class of dwarf eggs and in two groups of normal eggs previously studied[5] are given in table 2.

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[5] Pearl, R. and Surface, F. M. 1914. A Biometrical Study of Egg Production in the Domestic Fowl. III. Variation and Correlation in the Physical Character of the Egg. U. S. Dept. Agr. Bur. Anim. Indus. Bul. 110, Pt. III, pp. 171-241.

Curtis, M. R. 1914, b. A Biometrical Study of Egg Production in the Domestic Fowl. IV. Factors Influencing the Size, Shape and Physical Constitution of Eggs. Archiv f. Entw. Mech., Bd. 39, pp. 217-327.

TABLE 2.

Constants of Variation in Size and Shape in the Several Types of Dwarf Eggs and in Normal Eggs.

CHARACTER.	PROLATE SPHERODAL SHAPE.			CYLINDRICAL SHAPE.		All normal first year eggs from 22-bird flock.	All eggs laid by 850 birds on Feb. 13, 1908.
	Yolkless.	Some free yolk.	A small yolk.	Yolkless.	Some free yolk.		
Number of eggs	83	138	26	8	4	3,180	450
Length.							
Mean	35.27 ± .37	35.84 ± .34	41.35 ± .50	41.68	31.3	55.70 ± .03	56.32 ± .08
Standard deviation	5.03 ± .26	5.88 ± .24	3.81 ± .36	–	–	2.41 ± .02	2.39 ± .05
Coefficient of variation	14.26 ± .76	16.40 ± .68	9.22 ± .87	–	–	4.33 ± .04	4.24 ± .09
Breadth.							
Mean	28.23 ± .24	28.94 ± .21	32.38 ± .38	23.59	15.73	41.14 ± .02	41.92 ± .04
Standard deviation	3.20 ± .17	3.61 ± .15	2.87 ± .27	–	–	1.41 ± .01	1.38 ± .03
Coefficient of variation	11,34 ± .60	12.48 ± .51	8.85 ± .83	–	–	3.44 ± .03	3.29 ± .07
Index.							
Mean	80.75 ± .44	81.54 ± .36	78.88 ± .59	57.57	48.67	73.95 ± .04	74.52 ± .12
Standard deviation	5.96 ± .31	6.31 ± .26	4.41 ± .42	–	–	3.30 ± .03	3.79 ± .09
Weight.							
Mean	17.11 ± .43	18.35 ± .41	24.81 ± .81	15.24	10.63	52.92 ± .06	55.26 ± .15
Standard deviation	5.86 ± .31	7.14 ± .29	6.31 ± .57	–	–	5.01 ± .04	4.62 ± .10
Coefficient of variation	34.24 ±1.99	38.90 ±1.80	24.70 ±2.45	–	–	9.46 ± .08	8.36 ± .19
Weight.							
Mean	–	–	26.24 ± .82	–	–	–	–
Standard deviation	–	–	5.29 ± .63	–	–	–	–
Coefficient of variation	–	–	20.15 ±2.50	–	–	–	–
Yolk weight.							
Mean	–	–	4.27 ± .34	–	–	15.77 ± .02	–
Standard deviation	–	–	2.01 ± .24	–	–	1.78 ± .02	–
Coefficient of variation	–	–	47,12 ±6.75	–	–	11,31 ± .11	–
Albumen weight.							
Mean	–	–	17.79 ± .53	–	–	31.55 ± .05	–
Standard deviation	–	–	3.15 ± .37	–	–	3.87 ± .04	–
Coefficient of variation	–	–	17.69 ±2.18	–	–	12.27 ± .11	–
Shell weight.							
Mean	–	–	4.18 ± .19	–	–	5.12 ± .01	–
Standard deviation	–	–	1.10 ± .13	–	–	.71 ± .01	–
Coefficient variation	–	–	26.37 ±3.35	–	–	13.86 ± .13	–

By means of the data given in Table 2 it is possible to compare the size, shape and degree of variability of the several groups of dwarf eggs both among themselves and with normal eggs.

A. SIZE RELATION OF DWARF AND NORMAL EGGS.

1. All classes of dwarf eggs are lighter in weight and both shorter and narrower than normal eggs. This fact is of course obvious from the most casual inspection of dwarf and normal eggs.
2. The cylindrical eggs studied were much lighter in weight, decidedly narrower, but slightly longer than the eggs of the prolate spheroidal type.
3. Small yolked dwarf eggs are significantly smaller than normal eggs and larger than the other classes of dwarf eggs. That is the small yolked eggs are nearer the size of normal eggs than are dwarf eggs with little or no yolk.
4. The average length, breadth and weight are all slightly higher for dwarf eggs which contain some free yolk than for yolkless dwarf eggs. These slight differences are not certainly significant.

These results confirm the evidence from a study of normal[6] and multiple yolked[7] eggs that the amount of yolk (or other nucleus) present in the oviduct is an important factor in determining the amount of albumen secreted in a given case.

B. THE RELATIVE SHAPE OF DWARF AND NORMAL EGGS.

Table 2 also gives data for a study of the comparative shape of the several classes of dwarf and of normal eggs. It has already been noted that there are two distinct shape groups of dwarf eggs, cylindrical and prolate spheroidal eggs. The cause for the distinctly different form cannot be certainly decided from the material at hand. In several cases of cylindrical dwarf eggs the form of the nucleus was not noted. However, in a few pronounced cases it was noted that the nucleus of coagulated fibers of albumen was drawn out in a line parallel to the long axis of the egg. In the prolate spheroidal eggs the nucleus is of globular form. That is, its shape is comparable to the shape of a normal yolk. All the eggs with small formed yolks were of the prolate spheroidal type. It seems probable that the form of the stimulating nucleus is one of the factors in determining the shape of the egg.

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[6] Curtis, M. R. 1914, a. Studies on the Physiology of Reproduction in the Domestic Fowl. VI. Double and Triple-Yolked Eggs. Biol. Bul. Vol. 26, pp. 55-83.

[7] Pearl, R. 1910. A Triple-Yolked Egg. Zool. Anz., Bd. 35, pp. 417-423.

A comparison of the mean indices shows, first, that cylindrical dwarf eggs are longer in proportion to their breadth than are normal eggs, while prolate spheroidal eggs are proportionately shorter, and second, that dwarf eggs with small yolks are nearer the shape of normal eggs than are dwarf eggs without formed yolks.

It has been noted that indices for dwarf eggs with small yolks are higher than those for normal and lower than those for other prolate spheroidal eggs. The order for the value of index is thus the reverse of the order for the size characters. Later it will be shown that within each group of dwarf eggs the index is negatively correlated with weight. In earlier investigations[8] it has been shown, first, that the indices for multiple yolked eggs lie below the range of variation for the indices of normal eggs and, second, that within the normal eggs of an individual the index is negatively correlated with weight. The results from the study of dwarf eggs therefore extend the former evidence that the smaller the egg the broader it is in proportion to its length. Two factors may be working together to produce this negative correlation between index and weight. First, the greater the long diameter of the nucleus, be it yolk drop, normal yolk, or two or three yolks in tandem, the longer will be the area of oviduct stimulated at the same time and, second, when a plastic body is forced (by peristalsis) through an elastic tube the tube will offer more mechanical resistance to the passage of a large than a small body. The oviduct will therefore exert a greater elongating pressure on a large than on a small egg. This mechanical factor is probably of great importance in determining the shape of the egg.

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[8] Curtis 1914 a and b. Loc. cit.

C. THE RELATIVE VARIABILITY OF DWARF AND NORMAL EGGS.

Table 2 gives also the data for comparing the variability of the different classes of prolate spheroidal dwarf eggs with each other and with normal eggs. In comparing classes where the absolute difference in size is as great as it is between normal and dwarf eggs the coefficients of variation are more accurate measures of relative variability than are the standard deviations. In order to determine whether or not the apparent differences in degree of variability shown by the several classes is significant it is necessary to compare the coefficient of variation (given in Table 2) for each character in each group with the coefficient of variation for the same character in each of the other groups. If such comparisons are made, and if in each case the difference in the coefficients compared is considered in relation to its probable error, we find the following relations between the degree of variability in the several classes.. First, normal eggs are significantly less variable than the least variable class of dwarf eggs (small yolked dwarfs) in length, breadth, egg weight, yolk weight and probably shell weight. The significance of the smaller variation in albumen weight is doubtful. Second, small yolked dwarf eggs are almost certainly less variable than other dwarf eggs in length and probably also in weight. The significance of the smaller variation in breadth is doubtful. Third, the somewhat greater variation in every size character in the dwarf eggs with free yolk than in the yolkless eggs is not certainly significant. That is, it may be due to errors in sampling. In respect of shape the only deviation which can be considered of even probable significance is the difference between yolkless and small yolked dwarfs. That is, normal eggs and small yolked dwarf eggs are probably less variable in shape than dwarf eggs without a formed yolk.

The relative variability of the size characters within each group are also of some interest. In both normal and dwarf eggs the size characters may be arranged in the order of their variability as egg weight, length, and breadth.

IV. The Interrelation of the Dimensions Shape and Weight of Each Class of Dwarf Eggs Compared to the Same Relations in Normal Eggs.

We have seen that the dwarf eggs of each group vary greatly in each dimension and in weight and shape. We may now consider the correlation in the variation of the several characters in prolate spheroidal[9] dwarf eggs of each class.

The correlations studied are length with breadth, breadth with weight, length with weight, index with weight, yolk weight with egg weight and yolk weight with albumen weight. On account of the small number of dwarf eggs of known yolk weight the correlations involving yolk weight were calculated directly from the data. In the case of the other pairs of characters the usual correlation tables were made for each class of dwarf eggs.

Table 3 shows the correlation coefficients with their probable errors and also similar coefficients for normal eggs.

From Table 3 the following points may be noted:

1. In each class of dwarf eggs the correlation between the two dimensions is positive and is certainly significant. That is, a broad dwarf egg is also long and vice versa. The shape of the egg is no doubt determined by the action of the longitudinal and circular muscle fibers of the oviduct walls especially during the formation of the egg membrane and shell. The forming egg is a fluid body which tends to take a spherical shape when not under pressure. At the time an egg receives its membrane and shell a normal egg, and almost any dwarf egg, is larger than the normal diameter of the oviduct. It is, therefore, under pressure which tends to elongate it in the direction of the long axis of the duct. The degree of pressure and hence the resulting degree of elongation will depend on (a) the size of the egg compared to the diameter of a cross section of the duct, and (b) the relative tonus of the two sets of muscle fibers of the oviduct wall. A decrease in the tonus of the circular fibers, or an increase in that of the longitudinal fibers, or both, may counterbalance the increase in pressure due

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[9] Cylindrical eggs appear to show the same relations among themselves as the prolate-spheroidal eggs but the number was too small to determine the significance of the relationship.

TABLE 3.

Showing the Correlation Coefficients for the Size and Shape Characters of the Dwarf and Normal Eggs.

Kind of Eggs.	Number of eggs.	Correlation Coefficients.					
		Length and breadth.	Length and weight.	Breadth and weight.	Index and weight.	Yolk weight and egg weight.	Yolk weight and albumen weight.
Free yolked dwarf	138	.874 ± .013	.933 ± .007	.950 ± .006	—.408 ± .048	–	–
Yolkless dwarf	83	.844 ± .021	.924 ± .011	.919 ± .011	—.368 ± .064	–	–
Small yolked dwarf	26	.759 ± .056	.844 ± .039	.883 ± .029	—.092 ± .131	.940 ± .020	.789 ± .064
Normal (mean or individual coefficient for 22 birds)	3,180	.378	.753	.830	—.185	.818	.566
Normal (eggs laid by flock on a single day)	450	.084 ± .032	.580 ± .021	.836 ± .010	.085 ± .032	–	–

to an increase in the diameter of the egg. The fact that the correlation between length and breadth is significantly higher for dwarf eggs with little or no yolk than for small yolked dwarf or normal eggs may indicate that in these very small eggs there is little or no differential stimulus on the muscle fibers of the oviduct wall, but that there is such a stimulus when the egg is larger.

2. Length and breadth are both highly correlated with weight. That is a large egg is both broad and long. These relations are also true for normal eggs.

3. The index-weight correlations are negative and they are significant for dwarf eggs with little or no yolk. That is for these two groups of small dwarf eggs the larger the egg the longer it is in proportion to its breadth, or the larger the egg the lower the index. The bearing of this fact has already been discussed (p. 297).

4. The correlation between yolk weight and albumen weight in dwarf eggs with small yolks is higher than the average correlation between yolk weight and albumen weight within the normal eggs of a single individual. This high correlation between yolk weight and albumen weight in dwarf eggs with small yolks adds to the evidence already presented (p. 297). that the amount of yolk present in the duct is an important factor in determining the amount of albumen secreted and thus both directly and indirectly influences the size of the egg.

V. The Frequency of the Occurrence of Dwarf Eggs Compared to Normal Eggs and of Dwarf Egg Producers Compared to Birds which do not Lay Dwarf Eggs.

The 298 dwarf eggs collected were produced by nine different flocks. During any year a few dwarf eggs may have escaped collection by being broken in the nest or laid on the floor and lost in the litter. This loss cannot have been large at any time. However, in order to guard against the possibility that there was an unequal loss during the several years the two years of highest dwarf egg production were selected for a comparison between the frequencies of dwarf and normal eggs.

The frequency of the occurrence of dwarf eggs compared to normal eggs may be determined by calculating the percentage of all the eggs produced which are dwarf. For convenience this percentage may be multiplied by 100. This number represents the number of dwarfs in 10,000 eggs. This percentage was calculated for each of the two years of highest dwarf egg production, i. e., 1911-12 and 1914-15. These data are given in Table 4.

TABLE 4.

Showing for the Years 1911-12 and 1914-15 the Total Number of Eggs, the Total Number of Dwarf Eggs and the Number of Dwarf Eggs per 10,000.

YEAR.	Total number of eggs.	Total number of dwarf eggs.	Number of dwarf eggs per 10,000.
1911-12	63,176	59	9.3
1914-15	88,560	72	8.1
Total	151,736	131	8.6

From these data it is seen that during the two years of maximum dwarf-egg production the proportion of dwarf to normal eggs was 8.6 dwarfs in 10,000 eggs, or one dwarf in 1,158 eggs. Warner and Kirkpatrick[10] show that during two laying contests at Storrs, Connecticut, 199,137 eggs were produced of which 103 weighed less than .09 lb. (40.82 gms.). From these figures we see that they obtained 5.2 dwarf eggs per 10,000, or one dwarf egg in 1,933 eggs.

The nine flocks which laid the dwarf eggs considered in this investigation contained approximately 4,800 different individual birds. Of these 4,800 birds about 5 per cent. produced at least one dwarf egg. By means of the data given by Warner and Kirkpatrick (*loc. cit.*) we see that during the third and fourth laying contest at Storrs, Connecticut, 85 out of 1,820 birds, or, 4.67 per cent. laid one or more dwarf eggs. The close agreement of the two approximations indicates that about 5 per cent. of the birds in an average flock will produce at least one dwarf egg.

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[10] Warner, D. E. and Kirkpatrick, W. F. 1916. What the Size of Egg Means. Jour. of Heredity, Vol. VII, pp. 128-131.

VI. The Seasonal Frequency of Dwarf Eggs Compared to Normal Eggs.

Dwarf eggs are frequently found by poultrymen during the spring and early summer and somewhat less frequently at other seasons. During the eight years that these eggs have been collected at the Maine Station plant they have occurred during every one of the twelve months. However, 70.8 per cent. of them were laid during the five months from March 1 to July 31. During some years more than 80 per cent. were produced during these months. Table 5 gives the number of dwarf eggs produced each month for each of the eight years (1908-16). It also gives the percentage of all of the dwarf eggs (1908-16) and the percentage of the total annual yield of normal eggs (1899-1907)[11] produced during each calendar month.

This table shows that both dwarf and normal egg production is higher during the spring and summer than during the fall and winter. A comparison of the percentages at the foot of the table, however, shows that for May, June and July the percentage of the annual dwarf eggs is greater than the percentage of normal eggs. The monthly percentages of both normal and dwarf eggs are shown graphically in Fig. 52. It will be noted that the two polygons do not begin or end with the same month. The reason for this is that the data for the total egg production was collected for the September and October after the birds were one year old, while for the period during which dwarf egg production was studied, the data from September 1 to August 31, more nearly represents the data from a single group of birds.

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[11] These percentages were determined by Pearl, R. and Surface, F. M. 1911. A Biometrical Study of Egg Production in the Domestic Fowl. II. Seasonal Distribution of Egg Production. U. S. Dept. of Agr., Bur. of Anim. Indus. Bul. 110, Pt. II, pp. 81-170.

TABLE 5.

Showing Number of Dwarf Eggs Recorded Each Month from February 1, 1908, to February 1, 1916, and the Percentage of both Dwarf and Normal Eggs Produced During Each Calendar Month.

YEAR.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May	June	July	Aug.	Total
1907 and 1908	-	-	-	-	-	1	1	5	5	4	0	0	16[12]
1908 and 1909	0	0	0	0	0	3	7	5	1	3	0	1	20
1909 and 1910	2	1	1	0	0	3	7	5	5	0	10	0	34
1910 and 1911	0	1	2	3	1	2	3	3	12	6	4	6	43
1911 and 1912	2	1	2	2	2	0	7	7	10	17	2	7	59
1912 and 1913	1	1	1	1	3	0	1	0	7	1	1	0	17
1913 and 1914	0	3	0	0	2	0	4	8	4	5	1	0	27
1914 and 1915	1	0	6	3	4	3	5	8	7	10	20	5	72
1915 and 1916	0	5	2	2	1[13]	-	-	-	-	-	-	-	10[12]
Total	6	12	14	11	12	12	35	41	51	46	38	19	29.8
Per cent of total number produced during month	2.01[14]	4.03[14]	4.71	3.69	4.36	4.03	11.74	13.76	17.11	15.44	12.76	6.36	100
Perc ent of total annual yield of normal eggs produced during month 1899-1907.	6.36	4.27	3.59	6.91	9.08	8.44	12.50	12.30	10.80	9.67	8.44	7.64	100

[12] Years incomplete.
[13] Calculations in earlier parts of paper were completed before this egg was laid.
[14] These should follow August as they are for the end and not the beginning of the year.

From the diagram it is seen, as would be expected on the theory of chance, that during the months of heaviest normal egg production more dwarf eggs are produced than at other seasons. Yet it is also seen that the two curves are by no means parallel. The egg production curve rises gradually through the fall and winter to its spring maximum and then drops away even more gradually. The dwarf egg production curve does not rise during the fall and winter, but rises very abruptly during the spring to its maximum, which is three months later than the maximum for the normal egg curve. It remains relatively higher than the normal curve through the early summer.

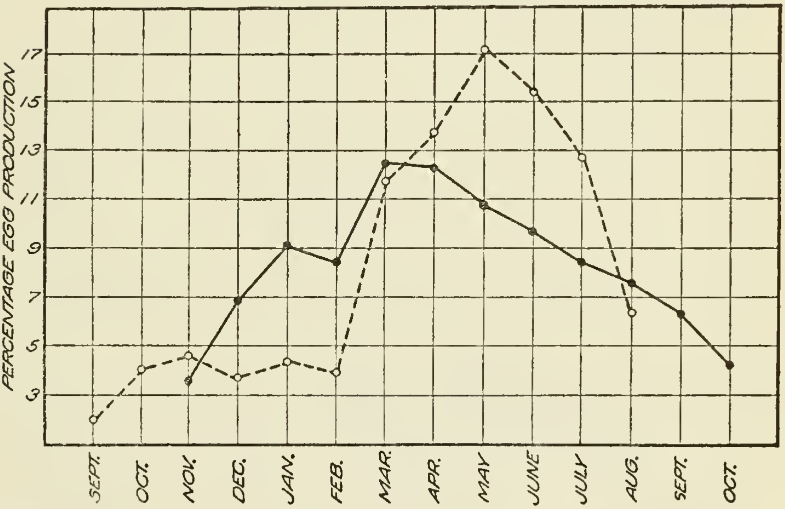

Fig. 52. Diagram showing the percentage of the yearly total egg production (8 year average, 1899-1907) and total dwarf egg production (8 year average, 1908-1916) which occurred during each month. Solid line = percentage of annual egg production. Dash line = percentage of annual dwarf egg production.

Since the data for the two polygons are derived from entirely different birds it is desirable to pursue the investigations farther and compare the number of dwarf eggs and the number of normal eggs produced by the same birds. The two years of maximum dwarf egg production 1911-12 and 1914-15 were selected for this study. The data for this study are given in

Table 6, which shows the total egg production, the dwarf egg production and the number of dwarf eggs per 10,000 eggs for each month of the two years combined. The data given in the last three columns are shown graphically in Fig. 53.

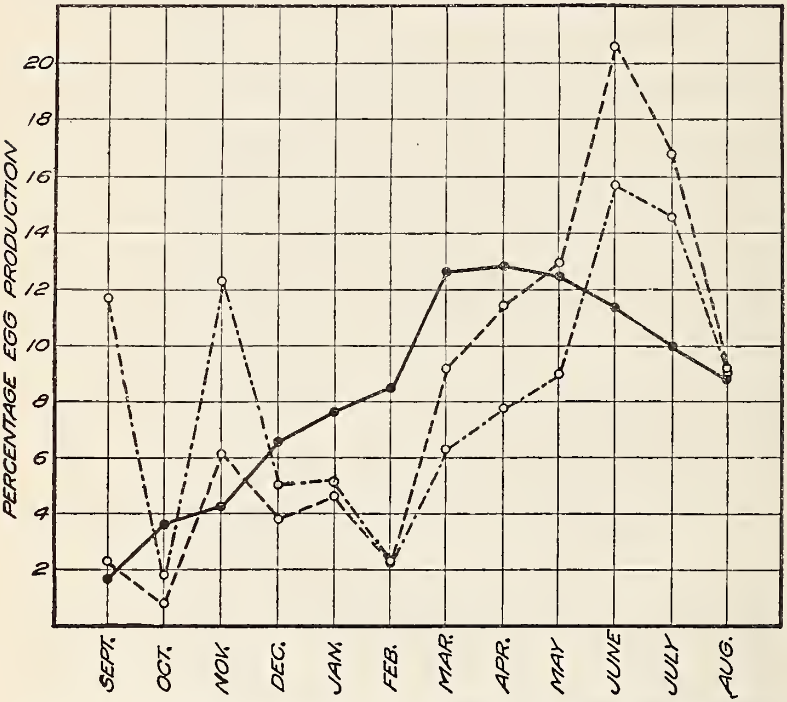

Fig. 53. Diagram showing for the years 1911-12 and 1914-15 combined the percentage of the yearly total egg production and dwarf egg production which occurred during each month and the per cent. (x 100) of the eggs produced each month which were dwarf. Solid line = per cent. of total yearly egg production per month. Dash line = per cent. of total yearly dwarf egg production per month. Dot-dash line = the per cent. (x 100) of eggs produced during the month which were dwarfs.

An examination of the diagram or the data given in Table 6 shows that not only is the actual number of dwarf eggs smallest during the winter, but that the number of dwarf eggs per 10,000 is also smallest. The irregular fluctuations of the fall are due to the fact that three birds which produced dwarf eggs because of a pathological condition of the sex organs laid

TABLE 6.

Seasonal Distribution of Dwarf Egg Production.

MONTH.	1911-12 AND 1914-15 COMBINED.				
	Total number eggs.	Number dwarf eggs.	Number dwarf eggs per 10,000 eggs.	Per cent. of total number eggs produced during month.	Per cent. of total dwarf eggs produced during month.
September	2,564	3	11.7	1.69	2.29
October	5,529	1	1.8	3.64	.76
November	6,484	8	12.3	4.27	6.11
December	9,917	5	5.0	6.54	3.82
January	11,560	6	5.2	7.62	4.58
February	12,784	3	2.3	8.43	2.29
March	19,135	12	6.3	12.61	9.16
April	19,292	15	7.8	12.71	11.45
May	18,789	17	19.0	12.38	12.98
June	17,201	27	15.7	11.34	20.61
July	15,157	22	14.5	9.99	16.79
August	13,324	12	9.0	8.78	9.16
Total	151,736	131	8.6	100.0	100.0

during these months. The small number of normal eggs produced at this season gives great weight to these dwarf eggs in calculating the number of dwarf eggs per 10,000. Both the actual number of dwarf eggs and number per 10,000 increase through the spring, reaching a maximum in early summer some months later than the maximum for normal egg production. It is thus shown that the dwarf egg production is actually highest, and also highest in proportion to the normal egg production, during the spring and early summer.

It appears that the disturbances in physiology which result in the production of dwarf eggs become more frequent with the onset of the natural breeding season and continue to increase in frequency during this season. The probable nature of these disturbances will be discussed later.

VII. DWARF EGG PRODUCTION BY BIRDS WITH NORMAL AND WITH PATHOLOGICAL OVIDUCTS.

The production of a dwarf egg is usually an isolated phenomenon. That is. a bird usually produces only one such egg. This fact is easily seen from Table 7.

TABLE 7.

Showing Number of Dwarf Eggs Laid by Each Bird which Produced One or More Such Eggs.

NUMBER OF DWARF EGGS LAID BY A BIRD.	Number of birds.	Per cent. of birds.	Number of eggs.
1	178	89.0	178
2	15	7.5	30
3	3	1.5	9
4	1	0.5	4
5	1	0.5	5
8	1	0.5	8
17	1	0.5	17
Total	200	100.0	251
Number of dwarf eggs laid by birds whose number was not known, i. e., mostly floor eggs			47
Total			298

From this table we see that of the 200 birds which produced one or more dwarf eggs, 178, or 89.0 per cent. produced only one, 15, or 7.5 per cent. produced two, and only 7, or 3.5 per cent. more than two. The figures given by Warner and Kirkpatrick (*loc. cit.*) for the birds in the Connecticut Station laying contest show an even larger percentage (94.11 per cent.) of the dwarf egg producers which lay only one dwarf egg. One bird laid 14 dwarf eggs and no normal eggs. Each of the other four (4.71 per cent.) laid two. It is thus apparent that the production of dwarf eggs is not usually an evidence of a permanent abnormality or derangement of the reproductive organs. This view is strengthened by a study of the egg records for the birds which produced dwarf eggs. In almost all cases these birds have a normal egg record. The dwarf egg is preceded and followed by normal eggs quite as though it were a normal egg. Only 11 (5.5 per cent.) of the 200 birds showed evidence of a permanent disturbance of the egg forming processes. It is evident that the disturbance which causes the production of a dwarf egg is usually of an accidental or at least temporary nature. However, there are certain pathological conditions of the oviduct which result in the formation of a dwarf egg instead of a normal egg.

The 11 cases where dwarf egg production appeared to be related to a permanent disturbance of the physiology of the sex organs include all of the cases where the bird produced more than three dwarf eggs, two that produced three, one that produced two, and four that produced only one dwarf egg. The production of a succession of dwarf eggs or of a long series of nesting records with one or two dwarf eggs should lead one to suspect a serious disturbance of the oviduct.

We will first consider dwarf egg production which is not associated with a morphological abnormality of the sex organs.

VIII. The Relation of Dwarf Egg Production by Normal Birds to the Age of the Bird and to the Position of the Egg in the Litter and Clutch.

A. *Age.* The age of the bird at the time the dwarf egg was laid could be determined in 202 cases where a dwarf egg was laid by a normal bird. The age frequency distribution is given below.

Age in Days.	*Dwarf Egg Frequency.*
150-209	11
210-269	14
270-329	22
330-389	65
390-449	52
450-509	19
510-569	4
570-629	0
630-689	3
690-749	6
750-809	2
810-869	2
870-929	0
930-989	0
990-1049	1
1050-1109	1
	202

It has already been noted that a large part of the birds are disposed of at the end of their first laying year. That is when they are 15 to 17 months of age. There were, therefore, many more chances for a bird to lay a dwarf egg during her first year than later in life. From data in hand it is not possible to decide whether or not a bird is more likely to lay a dwarf egg during the second or third year than during the pullet year. The flocks were not seriously depleted, however, until the end of the first laying year. It may be noted from the distribution that pullets are increasingly likely to lay dwarf eggs up to the time they are one year old and that the chances then decrease up to the end of the pullet year. The mean age for dwarf egg production among pullets may be calculated from the above distribution as far as and including the 450 to 509 day group. This mean is 361.96±3.75 days. That is, approximately one year. It is apparent also that the second year maximum falls in the 690 to 749 day group. That is, when the bird is approximately two years old. Dwarf eggs are also produced by birds approximately three years old. From these data we see that dwarf egg production, unlike multiple yolked egg production, is not associated with immaturity of the bird, but that it is most likely to occur during the height of the breeding seasons in the successive years. These are of course the seasons of highest normal egg production. In the case of a very few of the young birds and in an appreciable percentage of the old birds this is the only season in which the birds are in laying condition.

B. *Position in the litter.* There is a wide spread popular belief that a dwarf egg marks the end of a laying period or litter. This belief has found frequent expression in the literature from an early period to the present day.

Since both dwarf eggs and broody hens are most common during the breeding season, it is not unnatural that a relationship between the two is assumed by poultrymen who do not trapnest their birds. The use of the trapnest, however, soon dispells this illusion. Pearl, Surface and Curtis[15] say that "The laying of one of these eggs is popularly supposed to mark the end of a laying period. This belief is without foundation in fact. They may be produced at any time." Warner and Kirkpatrick (*loc. cit.*) have lately arrived at the same conclusion after a study of the data collected during two laying contests at Storrs.

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[15] Pearl, R., Surface, F. M. and Curtis, M. R. 1911. Poultry Diseases and Their Treatment, Orono, pp. 1-216.

A few birds lay practically continuously from the beginning of laying until the first moult. Usually, however, there are well defined laying periods which alternate with periods of non-production. The periods of production vary in extreme cases from two weeks to several months. In the present investigation any period of practically continuous laying, whatever its length, is considered a litter. In order to determine the relation of the production of a dwarf egg to its position in the litter it is necessary to standardize the litter in order to summarize the data from the different cases. If the ordinal number of the days in the production period be divided by the whole number of days in the period, the resulting fraction will represent the position in the litter of an egg produced on that day. By this method the litter position of each dwarf egg produced by a normal bird which completed the litter was obtained. The frequency distribution for litter position of dwarf eggs is given below.

Fraction of litter.	*Dwarf egg frequency.*
0-.099	26
.100-.199	19
.200-.299	10
.300-.399	16
.400-.499	13
.500-.599	21
.600-.699	24
.700-.799	15
.800-.899	10
.900-.999	29
	183

Mean = .506±.015
Standard deviation = .307±.011

This distribution is shown graphically in Fig. 54.

The irregular fluctuations of the frequency curve for the litter position of dwarf eggs are not greater than the expected fluctuations of a random sample of the same size drawn from a population evenly distributed over the range.[16] The present

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[16] For mathematical proof, see original paper.

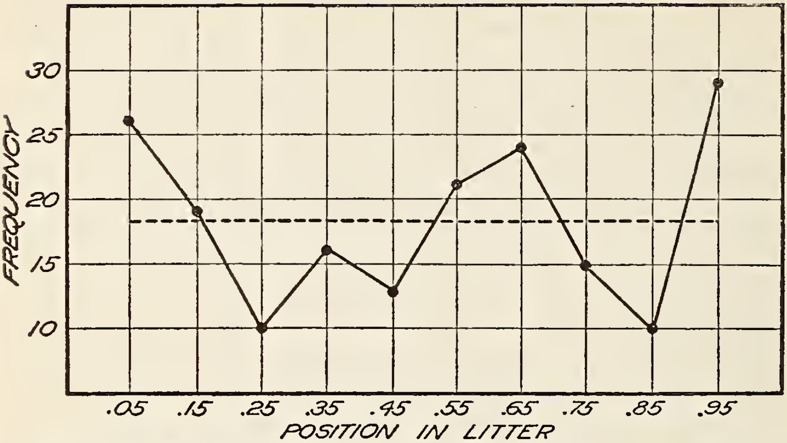

Fig. 54. Showing the number of dwarf eggs which occurred in each tenth of a litter. Dash line = the mean frequency.

data then indicate that a dwarf egg is equally likely to occur at any time during a period of production.

C. *The Position in the Clutch.* A fowl seldom lays on every day during a litter. The actual time between successive eggs depends on the rate of fecundity of the individual at the time. This rate differs greatly with the individual and with the season of the year. Since fecundity finds its manifestation in discrete units (eggs) the result of a very low rate is expressed by the production of an egg on a day preceded and followed by one to several days on which no egg is produced. A common low fecundity rhythm results in the production of an egg on every second day. More usually an egg is produced somewhat later on each of two or more successive days and then a day follows on which no egg is produced. The next egg is produced early on the following day. The litter is thus broken into a series of daily eggs, which we may call clutches, separated by one or more days on which no egg is produced. The size of a clutch varies from one egg to the extreme and unusual cases where a whole litter (sometimes of more than forty eggs) is laid in a continuous daily series.

The general acceptance of the notion that a dwarf egg marks the end of a period of production suggests an investigation of the position of the dwarf egg within its clutch. In 197 of the cases where a normal bird produced a dwarf egg the bird completed the clutch to which the dwarf egg belonged. Table 8 gives for every size of clutch the frequency distribution of clutch position of dwarf eggs.

TABLE 8.

Showing for Each Size of Clutch in which a Dwarf Egg was Produced the Frequency Distribution of Clutch Position of Dwarf Eggs.

Number of Eggs in the Clutch.	Ordinal Number of the Egg in the Clutch.															
	1st.	2nd.	3d.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	11th.	12th.	13th.	14th.	15th.	Total.
1	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50
2	26	20	–	–	–	–	–	–	–	–	–	–	–	–	–	46
3	10	19	13	–	–	–	–	–	–	–	–	–	–	–	–	42
4	5	5	7	7	–	–	–	–	–	–	–	–	–	–	–	24
5	2	4	3	2	5	–	–	–	–	–	–	–	–	–	–	16
6	0	2	2	0	1	0	–	–	–	–	–	–	–	–	–	5
7	1	1	0	0	1	3	0	–	–	–	–	–	–	–	–	6
8	0	0	0	0	1	0	2	0	–	–	–	–	–	–	–	3
9	1	0	0	1	0	0	0	0	0	–	–	–	–	–	–	2
11	0	0	1	0	0	0	0	0	0	0	0	–	–	–	–	1
15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2
Total	95	51	26	10	8	3	2	0	0	1	0	0	0	0	1	197

This table shows that 50 dwarf eggs occurred as one egg clutches. That is, no egg was produced on either the preceding or following day. Forty-six occurred in two egg clutches, the other egg being in each case a normal egg. Of these, twenty-six were the first and twenty the second of the two eggs. Similarly through the table we may compare the number of eggs produced in the successive positions in a clutch of any given size. The clutches in which dwarf eggs occurred vary in size from one to fifteen eggs. A study of this table shows no apparent uniform tendency for a dwarf egg to occur in any particular position in a clutch.

In order to summarize the data for the various sized clutches it is necessary to standardize the clutch. A clutch may be conceived as a line of definite length. This line may be divided into as many segments as there are eggs in the clutch. Each segment may be assigned a value equal to the fraction which the distance from the origin to the mid-point of the segment is of the whole length of the line. An egg then has a definite clutch position value expressed as a fraction of the clutch. These values are comparable for all sizes of clutches. For example, the value assigned to the middle egg of any clutch which contains an odd number of eggs is .500. A table was calculated which gives the value for each clutch position in each size of clutch. By means of this table the clutch position for each dwarf egg can be determined in terms which are comparable for all cases of dwarf egg production whatever the size of the clutch.

The clutch position frequency for the occurrence of dwarf eggs is given below.

Fraction of clutch.	*Dwarf egg frequency.*
0-.199	19
.200-.399	40
.400-.599	25
.600-.799	35
.800-.999	28
	147

Mean = .518±.015
Standard Deviation = .267±.011

This distribution is shown graphically in Fig. 55.

In this case as in the case of litter position the irregular fluctuations are not greater than would be expected to occur from errors of sampling.[17] The present data indicate then that a dwarf egg is equally likely to occur in any clutch position.

IX. PHYSIOLOGICAL CONDITIONS AND EFFECTIVE STIMULI WHICH LEAD TO DWARF EGG PRODUCTION.

It has been shown that dwarf eggs usually represent some *temporary* disturbance or some *accident* in the physiology of reproduction since such eggs are preceded and followed by normal eggs. The disturbance is most likely to occur during the height of the breeding season although it may happen at any time during the year. During any particular litter or clutch a dwarf egg is equally likely to occur at any time. Although the cause of dwarf egg production is usually of a temporary character there are cases where a bird lays only or chiefly dwarf eggs. Other birds produce normal eggs for some time and then become "habitual" dwarf egg producers. In the present section we shall consider the nature of the disturbances, both temporary and permanent, which lead to the production of dwarf eggs.

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[17] For mathematical proof, see original paper.

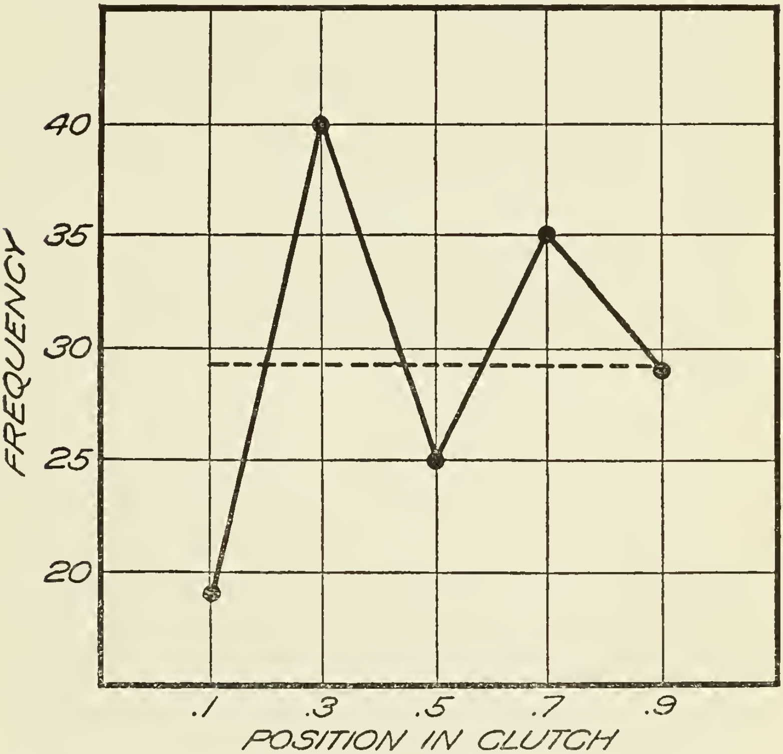

Fig. 55. Diagram showing the number of dwarf eggs which occurred in each fifth of a litter. Dash line shows the mean frequency.

On the basis of unpublished data Pearl, Surface and Curtis (*loc. cit.*) made a statement of the factors which were probably involved in dwarf egg production. The data on which this statement was based are included in the data used in the present investigations. The data then on hand indicated that three fundamental factors are concerned in dwarf egg production. "These are:

"1. The bird must be in an active laying condition; the more pronounced the degree of physiological activity of the oviduct the more likely are these eggs to be produced.

"2. There must be some foreign body, however minute, to serve as the stimulus which shall start the albumen glands secreting. This foreign body may be either a minute piece of hardened albumen, a bit of coagulated blood, a small piece of yolk which has escaped from a ruptured yolk, etc.

"3. It seems likely, though this is a point not yet definitely settled, that ovulation (i. e., the separation of a yolk from the ovary) must precede the secretion of albumen around the foreign body to form one of these eggs."

To a large extent the complete investigation confirms and extends these conclusions. The data which contribute to our knowledge of the physiology of dwarf egg production are the complete egg records and the autopsy records of dwarf egg producers.

A. EVIDENCE FROM THE EGG RECORDS AND AUTOPSY RECORDS OF DWARF EGG PRODUCERS WITH ABNORMAL REPRODUCTIVE ORGANS.

It has already been noted that the egg records for eleven of the 200 known dwarf egg producers showed that few or no normal eggs were produced after the dwarf egg or eggs. Such birds usually make nesting records, the dwarf egg occurring in a series of the nesting records. As an illustration the egg record of Case No. 1 is reproduced in Fig. 56.

From this record it may be seen that the bird was a heavy layer producing 162 eggs up to May 28. After this she produced only one normal egg (on June 26). The nesting records occurring in clutches indicate that the ovary passed through its normal cycles. Four dwarf eggs were produced in a series of nesting records.

Five of the eleven cases of dwarf egg producers cited above were autopsied and found to have several things in common. (1) Each bird was a normal high laying individual which became unable to produce normal eggs on account of a pathological condition[18] of the oviduct. (2) In every case the part of the duct affected was the posterior end of the funnel or the anterior end of the albumen secreting region or both. (3) The disturbance in each case was of a nature to constrict or prevent the normal expansion of the lumen of the duct. (4) In no case was the passage completely closed. (5) In each case there was convincing evidence that the ovary was in a normal reproductive cycle at the time the dwarf egg was produced.

Date.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals.	
Sept.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	n	..	..	n	..	...	..	..	...	n	...	1	..	1	1	..	3	
Oct......	..	1	1	1	1	1	1	1	..	1	1	1	n	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	..	27	
Nov...	1	..	1	...	1	n	1	1	1	1	1	1	1	1	1	1	..	1	..	1	1	1	1	1	1	1	1	1	1	1	..	25	
Dec..	..	..	1	1	1	1	..	1	1	1	1	1	1	..	1	1	1	1	1	1	1	..	1	...	1	..	..	n	n	1	1	21	
Jan.......	..	1	1	1	..	1	1	.	1	1	..	1	1	1	..	1	..	1	n	1	...	1	..	...	1	1	..	1	..	1	..	18	
Feb...	1	..	..	.	1	..	1	..	1	..	1	..	1	n	1	..	1	n	1	..	1	..	1	...	n	...	1	1	..	..	..	13	107
Mar.. ...	..	1	..	1	..	1	..	1	1	..	1	1	..	1	1	..	1	1	1	..	1	1	n	1	..	1	1	1	n	1	..	19	
Apr.. ..	1	n	1	1	1	1	n	..	1	1	1	n	1	..	1	1	n	1	1	..	1	1	1	1	..	1	n	..	..	..	..	18	
May..	1	1	..	1	1	1	1	1	1	n	1	..	1	..	1	1	n	..	n	1	...	1	1	n	1	1	..	1	..	..	..	18	162
June.. ..	n	..	..	n	n	n	n	n	..	n	n	n	n	n	n	n	..	..	n	n	n	n	n	n	n	1	n	..	n	n	..	1	
July....	n	n	n	1—	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	...	..	n	n	n	n	n	n	n	n	n	1—	
Aug..........	n	n	n	n	n	n	.	n	n	n	n	n	n	n	..	n	.	n	n	n	n	n	n	n	.	...	..	..	..	..	..	0	
Sept.........	..	..	..	..	..	..	..	..	..	.	n	n	n	n	n	n	n	n	n	n	...	n	n	n	n	n	..	n	..	n	..	0	
Oct..........	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	..	..	...	..	...	..	..	..	..	..	0	
Nov..........	..	..	..	..	..	..	..	..	..	n	n	..	n	n	n	n	..	..	n	..	1—	n	..	1—	..	1—	n	.	n	n	..	3—	
Dec..........	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	n	..	..	..	...	..	..	...	..	...	..	..	..	..	..	0	
Jan....	n	..	..	n	n	n	..	..	..	..	..	n	..	n	..	n	.	..	..	..	...	..	..	...	..	...	..	..	..	..	..	0	
Feb..	..	..	..	.	..	..	..	..	D	..	..	..	..	..	..	..	..	..	..	..	...	..	..	...	..	...	..	..	..	..	..		

a "1" denotes a normal egg, "1–" a dwarf egg, "n" a visit to the trap nest but no egg, and "D" date killed for data.

Fig. 56. Egg record of Case No. 1, "1" denotes a normal egg, "1—" a dwarf egg, and "n" a visit to the trap nest but no egg.

Five of the sixteen[19] dwarf eggs produced by these birds contained as a nucleus a small quantity of yolk not enclosed in a vitelline membrane. This yolk was no doubt a part of a normal yolk, the rest of which was absorbed by the visceral peritoneum. Three of the five birds were absorbing yolk in this manner at the time of autopsy. The presence of a part of a yolk in the egg may have been due to any one of several causes. The three which seem most probable are the following:

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[18] Four of the five cases had tumorous growths on the walls of the duct. In two cases these involved a large part of the funnel and albumen secreting region. In the other two the affected tissue was confined to a narrow band in the lower funnel or albumen secreting region. In the fifth case there were two constrictions of the duct in the anterior end of the albumen secreting region. The constrictions were separated by one centimeter of duct with a normal diameter. The tissue in these constrictions did not appear pathological.

[19] In two other cases the presence or absence of yolk was not recorded.

1. A yolk may have been broken during its passage into the duct and only a part of it may have entered the duct.

2. A part of a yolk ovulated into the body cavity and broken either before or after ovulation may have been picked up by the funnel.

3. A normal yolk may have entered the duct and being unable to pass the pathological portion may have been broken and a part of it extruded into the body cavity. The remaining portion may have passed the obstruction, becoming the effective stimulus for the formation of the egg envelopes.

The effective stimulus in the case of the dwarf eggs which do not contain any yolk is difficult to ascertain. Some of these eggs contained what were apparently normal chalazae. Most of them contained coagulated fibers which resembled the fibers of which chalazae are formed. It is possible that in some or all of these cases a normal yolk has entered the duct, stimulated the upper duct to secrete chalazae and some albumen, passed as far as the obstruction and then been extruded, leaving behind sufficient chalazae and albumen to furnish the mechanical stimulus necessary for the completion of the egg. Some of these eggs contained lumps of hardened albumen which may have arisen from albumen left in the duct or abnormally secreted. When the ovary is in a particular condition such a mechanical stimulus may cause the secretion of the egg envelopes. It must be kept in mind, however, that a dwarf egg did not occur unless the ovary was actively producing yolks. In none of the above mentioned cases was it impossible that a yolk had entered the duct and started the formation of the egg.

B. EVIDENCE FROM THE EGG RECORDS AND AUTOPSY RECORDS OF NORMAL DWARF EGG PRODUCERS WHICH WERE AUTOPSIED.

Attention has already been called to the fact that while occasional cases occur where dwarf egg production is due to a permanent disturbance of the reproductive apparatus it is in general not associated with such a condition. In fact a dwarf egg may occur at any time in a clutch or litter. The production of normal eggs continuing as if the dwarf had been a normal egg.

The autopsy records of normal birds which produce one or occasionally two or three dwarf eggs at wide intervals show that the sex organs are morphologically normal. In the cases where autopsy immediately followed the production of the dwarf egg the sex organs were in full functional activity and in every case but one the body cavity contained free yolk, indicating that all or a part of a yolk had failed to enter or had later been extruded from the duct. In one case the follicle had failed to rupture completely and was draining yolk from the torn yolk membrane. A part of this yolk was free in the body cavity and a part was in the dwarf egg.

C. EVIDENCE IN CASES WHERE A DWARF EGG FORMS A PART OF A COMPOUND OR A DOUBLE EGG.

1. *Compound eggs of which one part is a dwarf egg.*

Recently an abnormal egg was produced by a bird in the Station flock which gives additional evidence as to physiological conditions and nature of stimuli which may result in the production of a dwarf egg. The shell of this egg is shown in Figs. 57 and 58. This egg was a compound egg. The two parts were of quite unequal size. The component which filled the larger part of the shell contained a normal yolk in a normal membrane but there was a slight tear in this membrane and free yolk was protruding from this tear. The hole which faced the small component egg was quite small and little of the yolk had escaped. This part of the egg had normal chalazae and thick and thin albumen. The other part which filled the small portion of the shell contained a drop of free yolk surrounded by a thick albumen envelope which was quite distinct from the albumen of the large part of the egg. No thin albumen was present in this part of the egg. An incomplete shell membrane separated the two components.

The fact that when an egg is entering the isthmus as much and only as much of it as has passed in is covered with mem-

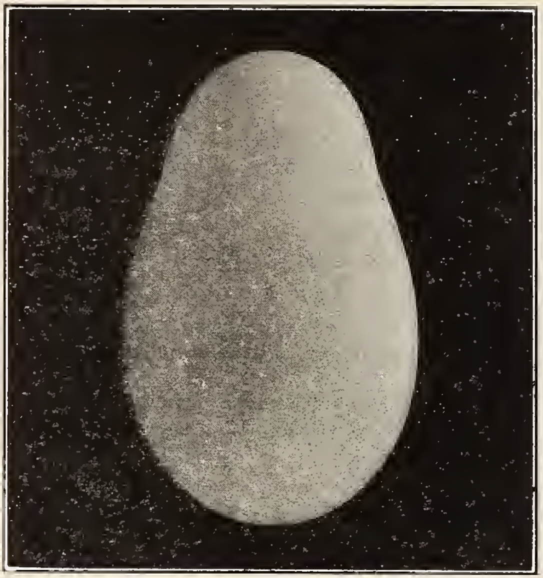

Fig. 57. Outside view of a compound egg which was composed of two albumen masses partly separated at the level of the seam in the shell by an incomplete egg membrane. The larger component contained a normal yolk with a slight puncture in the yolk membrane. The smaller one contained a drop of yolk which apparently came from the yolk in the other part.

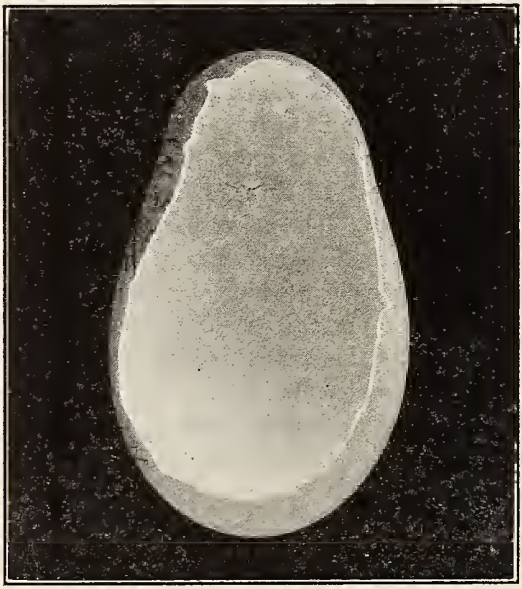

Fig. 58. Inside view of shell of the egg shown in Fig. 57.

brane was first noted by Coste,[20] and has since been observed by many investigators including the authors. Since the compound egg was formed of two parts imperfectly separated by a fold of membrane, they must have united after all of the albumen was formed and before the whole of the first component had passed into the isthmus. That is, this compound egg evidently represents the union of a dwarf and a nearly normal egg at the anterior end of the isthmus.

Two other compound eggs where one component was a dwarf and the other a normal egg have been produced at the Station plant. In both of these cases the membrane of the yolk in the normal egg was uninjured. In neither case was there any yolk in the dwarf egg. The only visible nucleus in each case was a mass of chalaza-like coagulated albumen fibers.

2. *Double eggs in which the enclosed egg and sometimes also the enclosing egg was a dwarf egg.*

The double or enclosed eggs observed at the Maine Station are described in a recent paper.[21] It seems necessary to summarize here those cases in which one or both of the components was a dwarf. In three cases a dwarf egg was included within a normal egg. Evidently in each of these cases a dwarf egg was returned up the duct and meeting a normal yolk was included with it in a common set of egg envelopes.

In six cases a small dwarf egg was enclosed within a larger dwarf egg. In one of these cases there was a drop of yolk in the outer egg. In two there was a small amount of yolk in the inner egg. In each case the dwarf egg was covered by egg membrane, while in two it also had shell. Each of the outer eggs had normal egg membranes and shell. In three cases there were bunches of coagulated albumen fibers resembling chalazae attached to the poles of the enclosed dwarf egg. The complete egg records for two of the six birds show dwarf eggs or nesting records, which suggest that there may have been a permanent disturbance in the morphology or physiology of the sex organs at the time the double egg was produced. In each of the other four cases the bird producing the double egg was a normal heavy laying bird. The double egg occurred in a normal clutch of from two to five eggs. In each case the double egg was the only abnormal egg ever produced by the bird.

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[20] Coste, M 1874. Histoire du developpement des corps organises. Tome I, Paris.

[21] Curtis, M. R. 1916. Studies on the Physiology of Reproduction in the Domestic Fowl. XVI. Double Eggs. Biol. Bul. Vol. XXXI, pp. 181-212.

D. EVIDENCE FROM EGG RECORDS AND EGG CONTENTS.

In case a bird which produced a dwarf egg was not autopsied the morphological condition and the physiological state of the sex organs at the time the dwarf egg was laid can be judged reasonably accurately by the egg record. In all cases not discussed under the section on "Abnormal Physiological Conditions Associated with Dwarf Egg Production" the dwarf egg was produced within a litter, all the other eggs of which were normal. As already shown, the dwarf egg took any position in the clutch and litter. In all cases there was abundant evidence from the egg record that the sex organs were in active condition and were capable of producing normal eggs.

In the center of the thick albumen of every dwarf egg examined was found some firmer material. In a number of cases this firmer nucleus was simply a few coagulated threads of albumen which resembled the threads of a normal chalaza. Sometimes the mass of threads has the appearance of a normal chalaza, but more often it is an irregular mass of untwisted threads. Such a mass of threads or one (rarely two) more or less perfect chalaza is present in nearly all the dwarf eggs.

Table 9 shows the number and percentage of each kind of dwarf eggs classified as to the nature of the contained nucleus.

TABLE 9.

Dwarf Eggs Classified According to the Nature of the Contained Nucleus.

NATURE OF NUCLEUS.	Number dwarf eggs.	Per cent. dwarf eggs.	Subtotals or per cents.
Drop of yolk, no yolk membrane	141	51.46	–
Broken yolk membrane with some yolk	10	3.65	55.11
Small complete yolk	27	9.85	64.96
Chalazal threads with or without lumps of coagulated albumen or blood clots	96	35.04	100.00
Total	274	100.00	

This table shows that in 9.85 per cent. of the dwarf eggs the stimulus to the active duct was an abnormally small yolk which for some unknown reason was produced and ovulated by the ovary. These cases apparently differ from normal egg production only quantitatively. That is, in the size of the stimulating yolk.

From this table we see also that 55.11 per cent. of all the dwarf eggs opened contained a portion of a yolk and 3.65 per cent. contained a broken yolk membrane. This fact in connection with the autopsy records already discussed (pp. 316-318) for birds killed while a dwarf egg was in the duct or immediately after one was laid, indicate that in at least 55 per cent. of all the cases of dwarf egg production the immediate stimulus to the active duct was a part of an egg yolk, the rest of which was absorbed from the visceral peritoneum. In one case the vitelline membrane of the yolk which furnished the stimulus was still within its ovarian follicle although part of the yolk was in the dwarf egg found in the shell gland and the most of the rest in the body cavity. In this case the yolk was broken during ovulation and only a part of it entered the duct. In the other cases it is impossible to tell whether the yolk was broken during or after ovulation. It is theoretically possible either that the yolk was ovulated entire into the body cavity and subsequently broken and a part taken up by the duct, or, on the other hand, it may have entered the duct and later been broken and a large part of it expelled.

It is seen from the table that 64.96 per cent. of all the dwarf eggs produced were apparently initiated by the presence of yolk in the duct.

The presence of almost normal chalazae in a few of the eggs without yolk suggests that a yolk may sometimes enter the duct, stimulate secretion of chalazae and then be extruded, leaving behind enough chalazae and albumen to furnish the necessary stimulation for the completion of the egg. In a few cases, however, the arrangement of the chalazal threads and albumen envelopes around a blood clot or a lump of hardened albumen make it seem probable that these particles have furnished the stimuli necessary to start the secretion of the egg envelopes.

X. THE RELATION OF DWARF EGG PRODUCTION TO OTHER OBSERVED PHENOMENA OF EGG PRODUCTION WHICH OCCUR IN NATURE OR HAVE BEEN EXPERIMENTALLY PRODUCED AND THE CONTRIBUTION OF THIS STUDY TO OUR KNOWLEDGE OF THE NORMAL PHYSIOLOGY OF EGG PRODUCTION.

It has already been noted that the six birds autopsied while an egg was in the oviduct or imeediately after one was laid had large empty follicles in the ovary. Five of them were absorbing yolk through the visceral peritoneum. In two cases the dwarf egg did not contain yolk. This suggested, first, that ovulation or a specific condition of the sex organs immediately accompanying it was the essential stimulus for the secretion of the egg envelopes by the duct, or second, that such a specific condition being present the secretion of the egg envelopes was stimulated by the small lumps of hardened albumen which seemed to be the nuclei of these dwarf eggs without yolk, or third, that a yolk had entered and then been expelled from the duct.

That neither ovulation nor any condition of the sex organs associated with it is sufficient alone to cause the formation of a dwarf egg is certain. Birds known to have ovulated into the body cavity for a long time, due either to a morphological or physiological (Curtis and Pearl 1915, *loc. cit.*) or surgical (Pearl and Curtis 1914, *loc. cit.*) disturbances, which prevented the yolk from entering the duct but did not otherwise disturb the mechanism, did not produce dwarf eggs. Some stimulus other than the condition of the sex organs is necessary to start the secreting activity of the duct. In normal eggs or in dwarf eggs with yolk this stimulus (mechanical or chemical) is furnished by the yolk.

The fact that all dwarf eggs without yolks contain some nucleus firmer than normal albumen, together with the fact that in one case where the bird had a dwarf egg with such a nucleus in the shell gland at autopsy no yolk was found in the body cavity suggests that when the ovary is maturing and ovulating successive yolks a mechanical stimulus may initiate the secretion of the egg envelopes.

The results of surgical experimentation show conclusively that in a certain stage of activity the oviduct responds to a mechanical stimulus by the secretion of the egg envelopes.

Various facts indicate that the functional condition of the oviduct depends upon some substance formed in the ovary usually at the time yolks are maturing but in certain pathological cases at other times also. This substance is probably an internal secretion carried by the blood since the ovary can cause the enlargement to functional size of a small piece of oviduct, the normal nervous connections of which have been destroyed. The fact that dwarf eggs are produced only when the bird is maturing and ovulating yolks and the fact that more than 50 per cent. of the trials to induce egg formation around artificial yolks were failures, suggest that the sex organs must be and must remain in *absolute* functional condition until the egg is completed.

SUMMARY.

1. An occasional individual of any breed of domestic fowls produces one or more small abnormal eggs. These eggs may be called dwarf eggs.

2. There are two distinct shape types of dwarf eggs: first, the prolate spheroidal or egg shaped type, and second, the cylindrical type. The prolate spheroidal shape is more common. In fact 95.4 per cent. of the dwarf eggs studied were of this type.

3. Dwarf eggs may be classified as yolkless, free yolked, or small yolked according to the yolk content.

4. Of the 274 dwarf eggs opened 35.03 per cent. were yolkless and 64.96 per cent. or nearly two-thirds contained yolk. The yolk was enclosed in membrane in only 9.85 per cent. of the dwarf eggs opened, while free yolk was present in 55.11 per cent. of these eggs.

5. Dwarf eggs with small yolks while distinctly smaller than normal eggs are significantly larger than dwarf eggs with little or no yolk.

6. A comparison of the relative size of the several groups of dwarf eggs, normal eggs, double-yolked and triple-yolked eggs furnishes a continuous line of evidence that the amount of albumen secreted depends to a large extent at least upon the degree of immediate stimulation due to the amount of yolk present.

7. Dwarf eggs with small yolks have shape indices which are higher than those for normal eggs and lower than those for other prolote spheroidal dwarf eggs. These differences in index in the three groups are the reverse of the differences in size.

8. This negative correlation between the shape index, and size extends the evidence from former researches that the smaller the egg the broader it is in proportion to its length.

9. Dwarf eggs of each class are exceedingly variable when compared to normal eggs. This greater variation occurs in all the physical characters measured, i. e., length, breadth, shape, index, egg weight, yolk weight, shell weight and possibly albumen weight.

10. Dwarf eggs with small yolk resemble normal eggs in degree of variability as well as in size and shape more nearly than do other classes of dwarf eggs.

11. The several size characters show different degrees of variation. They may be arranged from most to least variable as follows: egg weight, length and breadth. This arrangement is the same for dwarf and normal eggs.

12. The interrelation of the size and shape characters in prolate spheroidal[22] dwarf eggs of each class is as follows:

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[22] The same relations apparently also hold for cylindrical dwarf eggs but the number observed was too small to determine the degree of relationship.

a. Length and breadth, length and weight, and breadth and weight are significantly positively correlated in eggs of each group.

b. Index and weight are negatively correlated. The correlation is significant for dwarf eggs with little or no yolk.

c. In dwarf eggs with small yolks, yolk weight is highly correlated both with egg weight and with albumen weight.

13. During the two years of maximum dwarf egg production at the Maine Station plant the proportion of dwarf to normal eggs was one dwarf to each 1,158 normal eggs.

14. During the last eight years 5.15 per cent. of all the birds kept at the Maine Station plant are known to have produced at least one dwarf egg.

15. Both the actual dwarf egg production and the number of dwarf eggs per 10,000 eggs is lowest during the winter months. It increases through the spring, reaching a maximum in the early summer.

16. The production of a dwarf egg is usually an isolated phenomenon occurring only once or twice during the life of a bird. Only 3.5 per cent. of the birds which produced one or more dwarf eggs produced more than two.

17. A study of all the egg records and the available autopsy records for birds which produced one or more dwarf eggs, shows that, in most cases, the disturbance which caused the production of the dwarf egg was of temporary character and was not correlated with a morphological disturbance of the sex organs.

18. Eleven of the 200 dwarf egg producers, however, showed evidence that a permanent disturbance had occurred.. In these cases few or no normal eggs were produced after the dwarf egg or eggs, although nesting records indicate that the ovary passed through normal reproductive cycles.

19. Five of these cases were autopsied and all of them showed some pathological condition of the oviduct which interfered with the passage of the egg, but did not entirely close the duct.

20. In normal birds dwarf egg production is most likely to occur during the height of the breeding season. It is not associated with immaturity of the sex organs.

21. The popular notion that a dwarf egg marks the end of a period of production is without foundation. A dwarf egg is equally likely to occur at any time during a clutch or litter.

22. A dwarf egg may be overtaken by a normal egg and form one of the components of a compound egg similar to a double-yolked egg except that one part is a dwarf egg.

23. A dwarf egg after it has received its membrane or its membrane and shell, may be returned up the duct and be included in the succeeding normal egg, or it may act as the stimulus for the formation of a larger enclosing dwarf egg.

24. Dwarf eggs are produced only when the ovary is in the absolutely active condition associated with the maturing of yolks. This is true whether the bird has a normal or a pathological oviduct.

25. When the sex organs are in this condition a mechanical stimulation of the oviduct by an artificial yolk may result in the formation of a complete set of egg envelopes.

26. The mechanical stimulation need not begin at the funnel in order to be effective to the parts lower down.

27. The mechanical stimulation is local in its effect. That is, it is not transmitted down the duct any distance below the point to which it is applied.

28. Dwarf eggs may be, and probably often are, produced by the stimulation of an active duct by some material particle which is not yolk. At least 65 per cent. of the dwarf eggs studied, however, were initiated by an abnormal small yolk or by a part of a normal yolk. Certainly in some and probably in all the latter cases the rest of the yolk was absorbed by the visceral peritoneum.